Service and Science

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Abstract While there is a rapid growth in the number of researchers and practitioners joining the service science community, this community has not yet settled on precise answers to two fundamental questions: "What is service?" and "Where is the science (in service science)?" This chapter examines possible answers to these two fundamental questions from multiple disciplinary perspectives, and proposes the Abstract Entity-Interaction-Outcome Universals (AEIOU) theory to frame the science of service systems.

Keywords Service science · Service innovation · Service customization · Service systems · Value co-creation · Customer variability

1 Introduction

1.1 Two Fundamental Questions

What is service? Where is the science (in service science)? The emerging service science community has not yet settled on precise answers to these two fundamental questions. Existing disciplines from economics to marketing to computer science provide related, but different definitions of service. Also, each discipline contributing to the creation of the service science community has its own scientific approaches and methods that practitioners bring to bear. Service-oriented sub-discipline areas are forming. Some of these sub-disciplines are service oriented architectures in computer science, service systems engineering in industrial engineering, and knowledge-intensive business services in economics. With so many disciplines taking up the

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study of service phenomena, a deeper integration seems possible and needed. This chapter will gather up evidence and examine possible answers to these two fundamental questions.

In addition to majority views, minority views are on the rise in the service science community. In short, a paradigm shift is underway, as the service science community wrestles with these two fundamental questions. Before foreshadowing the established majority and rising minority views, the nature of the existing service science community is described. Ultimately, this community must reach a new consensus view, or be forced to accept that service science is merely a mosaic of many disciplines.

1.2 An Emerging Community

Ten interrelated drivers are shaping the growth of service phenomena in the world. This rapid growth is increasing the number of researchers and practitioners joining the service science community.

Global economic change is the first driver. More nations are investing to improve their service sectors – monitoring productivity growth, quality levels, regulatory compliance and innovativeness. For the last 50 years the economies of most developed nations have been dominated by what traditional economists refer to as the service sector, and yet service has been understudied in academia relative to its economic importance (Chesbrough and Spohrer 2006; Parasuraman et al. 1985, 1990). Economics, marketing and operations (including both operations research and operations management) were some of the first disciplines to begin scientific study of service and service systems, and more recently other areas of management, engineering, computing, design, law, as well as social and behavioral sciences have applied their unique methods in service-oriented specializations or sub-disciplines (Roth and Menor 2003; Demirkan and Goul 2006; Sen 1999; Spohrer and Maglio 2009). Increasing levels of automation and outsourcing in agriculture and manufacturing enterprises, has shifted labor and value creation into what traditional economists call the service sector (Anderson et al. 2007). Nations are a type of service system from a service science perspective. Citizens are both customers and providers. Nations have the responsibility of protecting the rights of their citizens. When the majority of citizens no longer live in nearly self-sufficient farming communities, the unemployment rate among adult citizens becomes a major concern.

ICT-enablement or technology change is the second driver. For the last 50 years, integrated circuits and other advanced technologies have increased in capability at an exponential rate. Nevertheless, many of the grand challenges facing the world's growing population, such as hunger, poverty, unemployment, and corruption can be framed as lack of access to resources and opportunities in a world of increasing abundance (Sen 1999, 2001). Information Technology (IT) or Information-and-Communications Technologies (ICT) is both enabling and stimulating the growth of new types of service offerings that can reach the under-served members of society to help them participate in new on-line labor markets as well as help people and organizations in need connect with people and organizations with value propositions that address those needs (Rai and Sambamurthy 2006; Sen 2001). ICT-enablement is helping all types of service systems improve internal operations as well as external interaction capabilities with other service systems.

Outsourcing is the third driver. Businesses whose customers are other businesses are on the rise. The growth of business-to-business (B2B) service is highly correlated with the amount of outsourcing by existing firms. This driver is also closely related to the rise in the use of ICT, which enables outsourcing. Service delivery centers have sprung up in India, China, Egypt, Philippines, and other emerging market nations, as work shifts to where the best skills are available at the lowest cost. The ability to enforce service level agreements (SLA), switch to alternative service providers easily, and resolve legal disputes across national boundaries has also helped enable outsourcing to flourish, and given rise to the rapid growth of B2B service. Businesses are a type of service system (Demirkan et al. 2005). Their sustained vitality depends on maintaining profitability or being acquired.

Business model change (value migration) is the fourth driver. As products become more complex, many customers will not buy a product without a service plan, and they often prefer access (leasing) over ownership. Therefore, traditional manufacturing firms like GE, IBM, Xerox, Rolls Royce, John Deere, and other have seen an increasing percentage of their revenue come from service offerings, rather than simply the sale of products. IBM has played a major role in helping to establish the service science community (IfM and IBM 2008; Spohrer and Maglio 2008). Modern businesses, including agricultural and manufacturing businesses, are service systems from a service science perspective. This new perspective breaks with the current majority view.

Where people live (demographic change) is the fifth driver. Cities and suburban areas are where most people are born or move to for a job, and therefore end up living their lives there. Most of the world used to live on farms in rural areas. Cities with their diverse jobs and service conveniences are attracting more and more of the world's population. As the world's population shifts from rural to urban areas and as national economies become dominated by the what economist call the service sector, or the knowledge economy, interest in service science has also been growing. Cities are a type of service system from a service science perspective (Heskett 1987; Heskett et al. 1990, 1994, 1997a, b).

How long people live (another demographic change) is a sixth driver. Also, an aging population world-wide is a related demographic change. People are living longer. This is creating more dependence on hospitals and hospital operations. Hospitals are a type of service system from a service science perspective.

The nature of family life is the seventh driver. The role of women in society has been changing rapidly in the last 100 years. As women have entered the workforce in developed nations, family incomes have risen and the demand for personal services has skyrocketed. Demand for child care, retail, hospitality, entertainment, information, mobile communications, fitness, and more are surging. Managing dual careers in volatile job markets has also increased demand for education and life-long-learning, fueling a growth in educational service for working professionals. Families are a very special type of service system from a service science perspective.

A rising education level is the eighth driver. Employees find higher education levels and life-long-learning required to participate in many career paths (Hefley and Murphy 2008; Mandelbaum and Zeltyn 2008). On the flip side, employers face the challenge of creating career paths to elevate employees over time into higher value creation and higher compensation roles. On the one hand, employers in both the private and public sector are using technology to reduce labor costs (number of employees used to provision a service) and improve reliability of outcomes per unit of management and governance costs through a higher degree of standardization and automation. The labor (employees) that are no longer needed must either be elevated into new roles or eliminated from the enterprise. Elevation into new roles typically requires a simultaneous increase in intra-and-inter-organizational communication skills and/or multidisciplinary project team communication skills (breadth) as well as specialized problem solving skills and new areas of expertise (depth). So called T-shaped professionals have both depth and breadth, allowing them to be more productive on teams and more productive life-long-learners who can adapt to new opportunities and challenges (Donofrio et al. 2009). The ability to lead and start new ventures, both inside and outside firm boundaries is also, highly sought. Service science provides a transdisciplinary framework that helps I-shaped professionals become more T-shaped over time. Individual people are service systems from a service science perspective.

A rising dependence on universities is the ninth driver. Universities create the skilled human-capital essential to national prosperity, and are also the source of new knowledge which is also essential to national competitiveness. The academic ranking of universities is driven by the quality of faculty and research centers at a university. In great cities with great universities, universities are also often in the top ten employers of their regions, helping to create many jobs for knowledge-workers. These great universities in many cases have a medical center and hospital as part of their operations, and in these situations the university is often in the top five employers of the region. Universities play a key role in society, providing a bridge for young adults into higher learning, jobs and independent living. Universities are service systems from a service science perspective.

A rising dependence on non-profit organizations is a tenth driver. Non-profit organizations exist at two ends of a spectrum and all points in between. At one end, are foundations with collectively trillions of dollars of wealth that they must invest in creating benefits for society consistent with their founder's intentions. At the other end of the spectrum, are non-profits that struggle to remain viable while delivering service to some of societies most under-served, who have nearly dropped out of modern society for reasons of mental illness, drug addictions, or in some cases those left homeless through a string of bad luck or non-productive life choices. In the middle of the spectrum, is a rich diversity of public broadcasting, museums, galleries, orchestra, religious organizations, educational institutions, charities, research centers, professional association, community athletic associations, and much more. Non-profits exist because increasing levels of wealth allow people to make donations, and increasing amounts of leisure time allow people to volunteer more. Non-profits are service systems from a service science perspective.

The above ten drivers are highly inter-related and interconnected. The growth in the diversity and number of entities interacting to create mutual benefits is driving the growth of service phenomena in the world. The growth of service phenomena is incenting disciplines to create service-oriented sub-disciplines to remain relevant. The growth of service-oriented sub-disciplines is in turn driving participation in the emerging service science community. Researchers join the community to look for coherence and deeper insights into service phenomena. Practitioners join the community to look for applications and insights that might improve operations or help create sustainable innovation, and thereby elevate the value of their service offerings to their customers and other stakeholders (Chase 1978, 1981; Chase and Dasu 2001). “Service up! Value up!” is one catch phrase used by practitioners.

As it matures, the service science community is gradually becoming increasingly focused on the study of holistic service systems, such as cities, universities, hospitals, luxury resort hotels, cruise ships, and the like, that can be described as somewhat self-contained entities that are a complex system of systems. In each of these somewhat self-contained entities, one finds a range of systems including transportation, water, food, energy, communications, buildings, retail, finance, health, education, and governance. The study of holistic service systems is especially challenging, because local optimization does not necessarily lead to global optimization and small changes in one subsystem can lead to large consequences in other systems (Alter 2008a, b; Blomberg 2008; Maglio et al. 2006, 2009; Spohrer et al. 2007). IBM’s Smart Planet initiative and the US National Academy of Engineering’s Grand Challenges of Engineering initiative have both brought a great deal of attention to system of systems, including cities, and many other types of engineered human-made systems (Donofrio et al. 2009; IBM 2004, 2009).

In sum, service science is an emerging area of research and practice for the transdisciplinary study and improvement of service systems (Chesbrough and Spohrer 2006; Demirkan et al. 2008; Spohrer and Riecken 2006; Spohrer et al. 2007). Service systems are complex business and societal systems that create benefits for customers, providers, and other stakeholders, and include all human-made systems that enable and/or grant diverse entities access to resources and capabilities such as transportation, water, food, energy, communications, buildings, retail, finance, health, education, and governance.

1.3 Majority and Minority Views

The next two sections explore important views on possible answers to the two fundamental questions. In both cases the majority view comes from a traditional economics perspective. The first question (what is service?) has a current majority view that is based on the traditional economist perspective (intangible product and service sector) and an emerging minority view that is based on a splinter marketing perspective (service-dominant-logic and value-cocreation). The second question (where is the science?) has a current majority view that is based on the traditional economist perspective (prices and productivity) and an emerging minority view that is based on a splinter systems perspective, closer to ecology (diversity, sustainability and quality of life).

2 What Is Service?

2.1 Tangible Versus Intangible

The majority view (established by traditional economists over 200 years ago) is that service is intangible product. Product is the output of an entity's efforts that may have value to other entities. If an entity produces a physical output that can be weighed, measured (using the physical sciences to ascertain its quality relative to a standard), and stored, then that entity (according to the majority view) is counted as a product-producing entity, and not-counted as a service-producing entity. For example, a farm produces bushels of corn that can be weighed and inspected via the methods of the physical science. Another classic example is that of a pin shop that produces tiny pieces of metal used to sew clothing or join sheets of material. These are physical or tangible outputs that can be weighed, inspected, and stored.

In contrast, the classic example of a service is a musician or a string quartet music group. Music is produced, but unless you are in the audience, you do not experience it. However, already we see our worldview today is quite different than 200 years ago. Two hundred years ago music could not be recorded and stored on digital media. Furthermore, measuring the frequency characteristics of the music would have been unimaginable except to a few members of the scientific community. To be sure, music boxes did exist and they were tangible products, but the majority of entities that produced music did so in live performances.

So 200 years ago, music required human labor to produce and could not be easily stored. So 200 years ago, music was a service. Today music is still a service in traditional economic statistics, even though music is most often listened to, by first being recorded and then played back by any number of devices, mundane and sophisticated. Because of technology, the majority of musical production has gone from the intangible product realm to the tangible product realm. And yet the older means of categorization and accounting are still used.

Without belaboring the point, if what is and is not a service is dependent on the technological capabilities of the time, then a precise definition is difficult as technological capabilities change rapidly, and we do not want our definitions to change that rapidly.

2.2 Ownership Versus Access

Another product-oriented approach to defining which entities produce service is based on the notion of ownership versus access. If an entity does not transfer ownership of a tangible product, but merely provides access, then that entity should be counted as a service-producing entity. So in the case of music, when you play back the song, you do not "own the song." You merely have "access to the song." Similarly, if a company makes cars to sell to customers, it is a product-producing entity, but if it rents the cars to customers, it is a service-producing entity.

The definition of service is now a legal definition. A service-producing entity is one that by definition provides access to resources it owns, but does not transfer ownership.

Again, without belaboring the point, what is and is not classified as a service-producing entity in national accounts is largely a matter of decisions made about entities at some point in history. Two more examples are needed before we suggest an alternative paradigm that avoids the problems of technological change and historical precedent.

2.3 Production Versus Coproduction/Transformation

By 1980, a number of economists were troubled by the lack of a positive definition for service-producing entities. Defining service-producing entities as a heterogeneous group of entities that were clearly not agriculture or manufacturing in nature was a negative definition that was for a number of reasons unsatisfying (Hill 1977). By this time the information economy was the focus of attention of many economists, and some of them set out to create a positive definition of service-producing entities (the service sector) that would fit the historical context well and accommodate the many new types of information services arising (Spohrer 1999).

Economists had already observed that in many service situations the cooperation of the customer was an essential characteristic (Fuchs 1968). For example, in education that student must labor to provide reasonable effort to gain benefits, and in health care the patient must eat right and exercise to gain benefits. Even listening to music requires some attention or cognitive resources of the customers to be committed. Coproduction of value was highly characteristic of many service situations, but not all. For example, newspaper delivery service requires very little customer effort. Nevertheless the commitment of customer resources and granting provider access to those resources, opened the doors for some new efforts to define "what is service?"

Within the product-centered or producing-centered worldview, some economists realized that an even more general framework would be needed to distinguish service-producing entities from product-producing entities. The key insight was noticing that many service-producing entities transform the customer entity in some way (e.g., education and health care) or transform a possession of the customer entity (e.g., washing the customer's car or depositing a newspaper on the customer's driveway).

Service as the transformation of an entity or an entity's possessions is a powerful, positive definition of service. A product-producing entity does not need customer resources during the production process, but a service-producing entity does need access to the customer or the customer's resources.

The only problem now was that the number of product-producing entities was dwindling, as economies of scales allowed fewer and fewer entities to produce most of the tangible products that customers need. Even more, with automation and off-shoring, the number of employees in developed economies needed by product-producing entities was dwindling as well. What had been the dominant part of the economy two hundred, even 100 years ago, was rapidly dwindling in number, though not dwindling in economic and political importance.

2.4 Outsourcing and Servitization

Just as some economists were celebrating a useful positive definition of service-producing entities by the end of the 1980s, one that was not dependent on technological capabilities of the time, two other dynamics began to raise concerns about the definition of product-producing entities. The first was outsourcing. Large manufacturing companies (product-producing entities) began depending on supply chains and procurement procedures, rather than vertical integration. In just a few decades, jobs that had been counted as part of product-producing entities shifted to service-producing entities. For example, janitors employed by a car manufacturer are not consider part of the service sector, but when the same employees doing the same work on the same assets are part of a cleaning service, suddenly they are counted as jobs in a service-producing entity.

The fact that an organizational change caused by outsourcing decisions could impact national statistics so substantially caused economists to scrutinize both their definitions of service-producing entities and goods-producing entities, but also the purpose of making this distinction (Argyris 1999).

Compounding the problems brought on by outsourcing, manufacturing companies began doing what might have been unthinkable a few decades earlier – they began adding service offerings to their revenue mix. From financing to maintenance to help-desks, expensive and complex manufactured products needed more customer service to appeal to customers.

2.5 Other Disciplines Join In

Economics was not the only discipline working to adapt their concepts and methods to better recognize the phenomenal growth of the service sector. Many academic disciplines that had grown up at a time dominated by product-producing entities were now seeking to prepare graduates who could solve problems and create innovations for a growing landscape of service-producing entities. Marketing, operations, management, engineering, computing, design, law, as well as social and behavioral sciences to name a few, were all adapting their content to prepare the majority of their students for jobs in the service sector.

Alternative definitions of service have been offered over time and together they could fill a large book (Edvardsson et al. 2005a, b). A sampling to illustrate the variety of ways to define service is presented below:

2.5.1 Economics

- Intangible products, unlike the tangible products of agriculture or manufacturing
- An exchange between economic entities that do not transfer ownership, but does grant access to resources and capabilities (access not ownership)
- An economic activity that requires access to customer resources or capabilities (coproduction)
- A transformation that one economic entity performs with the permission of a second entity, that transforms the second entity or a possession of the second entity (transformation)

2.5.2 Marketing

- The solution to a customer's problem
- A result customers want
- A customer-provider interaction that creates mutual benefits
- An economic exchange that does not transfer ownership to customers
- Customer benefits that are intangible, heterogeneous, inseparable, perishable
- The application of competence (e.g., resources, skills, capabilities) for the benefit of another entity

2.5.3 Operations

- Activities, deeds or processes, interactions that do not produce goods
- A process or performance, rather than a thing
- A production process that requires inputs from a customer entity

2.5.4 Computer Science

- A modular capability that can be computationally accessed and composed with others

2.5.5 Systems Engineering

- A system (with inputs, outputs, capacity limits, and performance characteristics) which is interconnected with other systems that may seek to access its capabilities to create benefits, and in which local optimization of the system interactions may not lead to global performance improvements

2.5.6 Design and Psychology

- An experience of a customer entity that results from that customer entity interacting with provider entities' offerings

2.5.7 Service Science

- Value-cocreation phenomena between interacting service system entities

What is common is the notion of entities interacting to achieve outcomes that are mutually agreeable and beneficial. What differs is contrasting the presence of tangible goods with intangible goods, contrasting access to resources with ownership of resources, contrasting implicitly agreeing with explicitly agreeing, contrasting directly interacting with indirectly interacting, etc. However, each discipline seems to focus on some aspect of the entities, interactions, and outcomes, and leaves out parts or add embellishments to suit their own specific disciplinary interests.

2.6 Enter Service-Dominant Logic

Clearly, economics is not alone. Other disciplines are working to adapt their concepts and methods to better recognize the phenomenal growth of the service sector. Over the last 50 years, marketing and operations were also evaluating alternative definitions of service. Courses taught traditional definitions to students, even as researchers pointed out the inadequacies and inconsistency in those definitions (Lovelock and Gummesson 2004). These same authors suggested that a paradigm shift might be necessary to make progress, and address the many anomalies resulting from inadequate definitions of service.

Within the marketing discipline, a view emerged known as service-dominant logic (Vargo and Lusch 2004a, b, 2006). Service-Dominant Logic (SDL) begins by suggesting that Goods-Dominant Logic (GDL) or the concept of product-producing entities as central, normal, and good is in fact exactly backwards. They begin by proposing that all economic interactions are service for service exchanges. Instead of service being intangible products, products are a form of packaged service or tangible service. The knowledge, competencies, and resources of the entity that offers the product are embedded in the product. For example, if a fish is offered, the fish embeds the competency of fishing, say baiting a hook, attaching the hook to a line and pole, knowing where to put the hook in the water, etc. In today's knowledge economy, this explanation resonates well with many people. All exchange is service for service (value-cocreation), because even when a tangible service (product) is part of the exchange, the product embodies the knowledge, competencies, and resources of the provider. Vargo and Lusch acknowledge this view was proposed in the early 1800s by the political economist Bastiat (Bastiat 1850/1979), and suggest Adam Smith's view of service was closely aligned with this view, but because of some misinterpreted examples in Smith's early writing the Goods-Dominant Logic view of service took hold (1776/1904, 1776/2000).

In the SDL view, products exist to make self-service easier, but having another entity provide the service may in fact be preferable. For example, one could use a lawn mower to mow one's lawn, or one could hire a yard service. What matters in the end is a mown lawn; both the lawn mower and the yard service are simply means to an end, or outcome. Levitt also noted that no one really wants a 1/8 in. drill, they want a 1/8 in. hole (Levitt 1972, 1976). The physical product is the means to an end, and the end or outcome is what is valued. The complexity of the means is a cost to achieve the desired outcome.

More recently, Vargo and Lusch argue that the entities capable of service for service exchange should be viewed from a systems perspective (2008a, b). While most of marketing has focused on B2C (Business to Consumer) exchange, they argue that from a systems perspective both the provider and the customer are complex systems, or resource integrators. For example, in one exchange an entity will be the customer, but in the next exchange that same entity may be a provider. B2B (Business to Business) exchange, clearly fits this pattern. In fact, entities are part of vast networks of other entities engaged in service for service exchange, as they apply their knowledge, competencies, and resources to create mutual benefits (Gummesson 1977, 2007).

2.7 New Questions

The majority view that service is intangible product is flawed. The music industry is categorized in the service sector, even though technological advances allow music to be easily recorded, stored, and distributed. The quality of music reproduction can be easily analyzed with today's technology, and precisely measured with the help of the physical sciences. As technological capabilities continue to advance, other supposedly service sector entities or intangible-product producers will be made tangible in a more advanced technological form. In addition, some businesses that are categorized as manufacturing businesses have completed outsourced their design and production to other businesses. They market and sell products (transfer ownership), but they do not contain a single manufacturing process or job in house (e.g, on-line T-shirt companies). The majority view of service as tangible product is flawed and no longer tenable, and yet national statistics still use categories that mischaracterize the in-house competencies of some firms and/or the characteristics of the output of some firms. In short, anomalies exist using the majority view.

If we accept what is still the minority (though rapidly growing) view of SDL that all economic exchange is service for service exchange, and that products are tangible service, then what is service? Service is the application of knowledge, competence, and resources for the benefit of another entity, and national economies and global markets can be viewed as entities engaged in service for service exchange (value-cocreation phenomena). To elevate their productivity, quality, compliance, and innovativeness entities need new knowledge, competencies, and resources. In short, anomalies can be resolved using the minority view.

Adopting the minority view of SDL, service interactions can be seen as service for service exchange, or value-cocreation phenomena between entities. These interactions may involve goods and money, which are viewed as mechanisms of indirect service for service exchange. Goods and money are tangible service (embodiments of past service). This view leads to a new set of questions for service scientists to answer, about the nature of entities, interactions, outcomes, and their dynamics over time:

- What types of entities are capable of service interactions?
- What types of interactions do service system entities engage in?
- What types of outcomes can result when service system entities interact?
- How do the types of entities and interactions change over time?
- How do the spatial distributions of types of entities change over time?
- How do the hierarchical structure and network relationships of entities change over time?
- How do the knowledge, competencies, resources owned and accessed by the entities change over time?

Some progress has been made by the emerging service science community in generating initial answers to these questions (Spohrer and Maglio 2009). However, nothing is settled, and much work remains.

2.8 Holistic Service Systems

Before addressing the second fundamental questions, *where is the science (in service science)?* which is the focus of the next section, it will be useful to further explore one class of service system entities known as holistic service systems (Spohrer and Maglio 2008; Donofrio et al. 2009). These types of systems vary enormously in scale and are very complex, but they also may be entering an era of accelerated innovation, or rapid learning from each other's best practices.

The types of entities that are capable of service interactions (service for service exchange) vary enormously in scale and structure. Nations, states, cities, hospitals, universities, businesses, non-profits, families, and individual people are capable of service interactions. They apply knowledge, competencies, and resources for the benefit of other entities, and engage in service for service exchange (value-cocreation). For example across nations, the populations can vary from hundreds of thousands (Iceland) to over a billion people (China), with differences in the structures associated with transportation, water, food, energy, communications, buildings, retail, finance, health, education, and governance.

Throughout most of history, farming communities existed as somewhat self-contained entities. Cities, surrounded by a network of smaller farming communities, were also somewhat self-contained. Similarly, for states and nations, throughout much of history they were largely self-contained entities that could exist for many generations with only minimal interactions with outside entities.

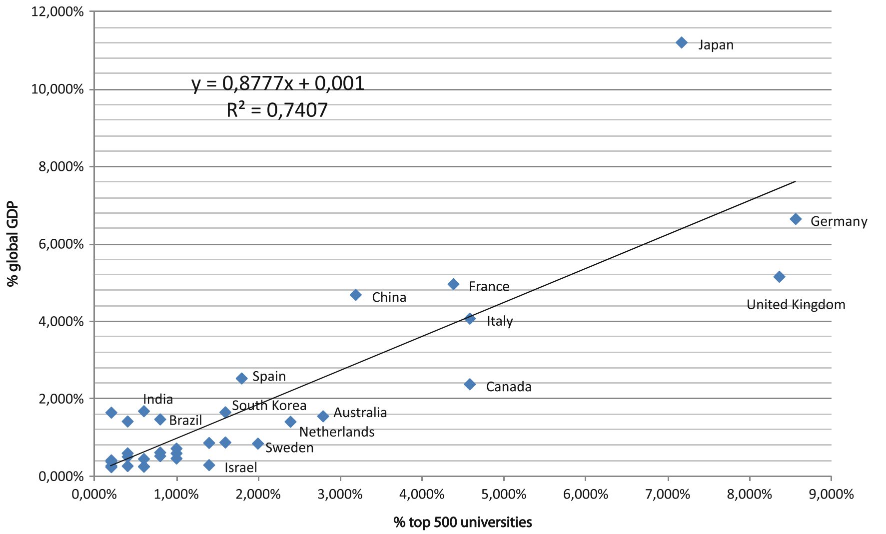
In short, they were (or at least had the potential to be) largely self sufficient. The knowledge, competencies, and resources, they needed to survive were largely contained within their population and local environment. While there are many benefits of being largely self sufficient, nevertheless, because they had minimal interaction with other entities, processes such as learning and sharing innovations, or best practices could be quite slow, and take many generations to jump from one holistic service system to another (Arc et al. 2003; Baumol 2002; Gadrey 2002; Gustafsson and Johnson 2003; Miles 2006, 2008; Pal and Zimmerie 2005; Spath and Fähnrich 2007).

In the interconnected world of today, if a nation, state, or city were to become cutoff from the rest of the world, quality of life would begin to suffer almost immediately. There is a much greater degree of interdependence amount service system entities today than in the past. Quality of life is a function of the quality of service from many systems such as transportation, water, food, energy, communications, buildings, retail, finance, health, education, and governance. In the world of today, quality of life is also a function of the quality of jobs in each of those systems. Furthermore, long-term, quality of life is a function of the quality of investments available to improve those systems year over year, so each generation benefits from a rising standard of living.

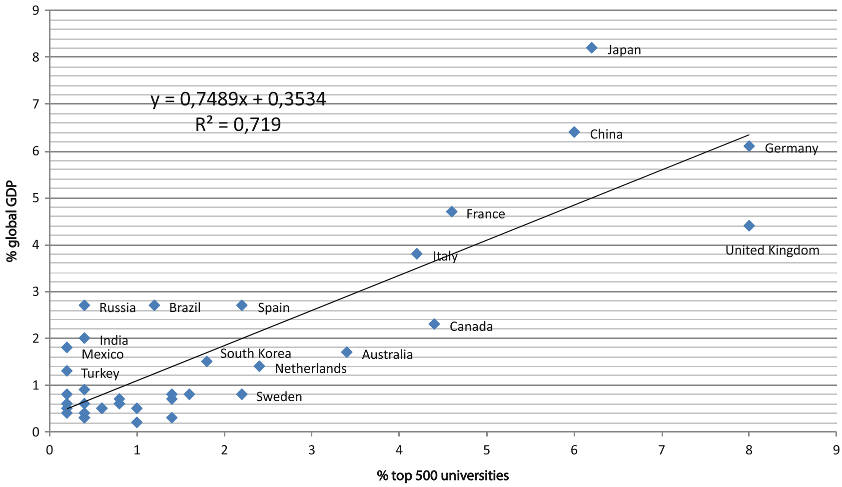
As noted in the introductory section above, the service science community is gradually becoming increasingly focused on the study of holistic service systems, such as cities, universities, hospitals, luxury resort hotels, cruise ships, and the like, that can be described as somewhat self-contained entities that are a complex system of systems.

Holistic service systems can improve by generating innovations on their own or copying the innovations of other holistic service systems. Holistic service systems include (to some degree) all of those sub-systems necessary for quality of life. Therefore, they can potentially benefit from improvements that first arise in another holistic service system.

Could we be entering an era of dramatically accelerated improvement of holistic service systems? There is some data that suggests this may be the case. For example, Fig. 1 below shows the correlation between a nation's percentages of world-wide GDP (Gross Domestic Product) and percentage of top-500-ranked universities. The strong correlation exists over time, and for nations like South Korea and China that have seen rapid GDP growth, there is also a rapid growth in



Correlating Nation's (2004) - % of WW GDP to % of WW Top-Ranked Universities
US is literally "off the chart" – but including US make high correlation even higher:
US % of WW Top-Ranked Universities: 33,865 %; US % of WW GDP: 28,365 %



2004-2009: Relative Change - China (+3,+2), US (–3.5,–5)
US is still "off the chart" – China projected to be "off the chart" in less than 10 years:
US % of WW Top-Ranked Universities: 30,3 %; US % of WW GDP: 23,3 %

Fig. 1 The correlation between a nation's percentages of world-wide GDP and % of top-500-ranked universities. (Source: http://www.arwu.org/ARWUAnalysis2009.jsp)

top ranked universities. This is likely a case of dual causality, in the sense that improved universities can help boost GDP, and improved GDP can help boost the quality of faculty, facilities, and graduates at the university.

	2006	1995	1984	Average Growth 1984-2006	*Includes University hospitals and SLAC (Note: LPCH's 2,037 employees were added 1995 with 2006 data) Datasources: All data except Stanford, Kaiser Permanente and Google, are from IT Business Journal. Data for Stanford, Kaiser Permanente and Google are self reported.
Stanford*	20,452	16,587	16,500	1.0%	
Cisco Sys. Inc.	16,500	1,023	n/a		
AT&T Inc.	15,500	n/a	n/a		
Santa Clara County	15,012	13,512	9,600	2.1%	
Kaiser Permanente	9,845	n/a	n/a		
Lockheed Martin	7,951	10,200	21,992	–4.5%	
Oracle Corporation	7,500	n/a	n/a		
City of San Jose	7,169	5,218	4,310	2.3%	
Hewlett-Packard Co.	7,000	15,000	18,033	–4.2%	
IBM	6,500	7,000	13,500	–3.3%	
Intel	5,700	5,000	6,000	–0.2%	
Google	5,337	n/a	n/a		
Applied Materials	4,156	5,122	n/a		
Between 1990 and 2008, private payroll employment in the Boston area grew by 10.2 percent; during the same period, employment at private colleges and universities rose by 18.4 percent.					

Fig. 2 University in the top ten largest employers

Furthermore, Fig. 2 below shows that universities are often in the top ranked 10 employers of a city or urban region, and often in the top 5 if the university includes a medical school and a hospital.

Cities and universities are tightly coupled holistic service systems. To a great degree, they rise and fall together. Changes in one affect the other. Furthermore, it appears we are entering an era, where our understanding of holistic service systems, will enable accelerated improvements, as they learn best practices from each other. Quality of life has the potential to improve consistently generation after generation, including quality of service from multiple systems, quality of jobs in those systems, and quality of investment opportunities based on more predictable change. The service science community is composed of researchers and practitioners working together to better understand service systems and to manage, engineer, and design best practice improvements.

3 Where Is the Science?

According to Webster's New Collegiate Dictionary, the definition of science is "knowledge attained through study or practice," or "knowledge covering general truths of the operation of general laws, esp. as obtained and tested through scientific method and concerned with the physical world" or "the organized body of knowledge people have gained using that system". Basically science refers to a system of acquiring knowledge – answering important questions about change and limits. This system uses observation, experimentation, and mathematics to describe, explain, and quantify phenomena. Less formally, the word science often describes any systematic field of study or the knowledge gained from it. What is the purpose of science? Perhaps the most general description is that the purpose of science is to produce useful models of reality.

Our second question (where is the science in service science?) has a current majority view that is based on the traditional economist perspective (prices and productivity) and an emerging minority view that is based on a splinter systems perspective (ecology and quality-of-life). Before describing the current majority view, which argues that service science is a sub-discipline of economics concerned with a particular type of economic production system that does not produce physical output, we briefly mention two other views that are more common than the emerging minority view. One suggests that service science is a misnomer, and that service management, service engineering, and service design are more appropriate terms. Supporters of this view argue that science is about the study of systems as they have evolved naturally, and that the quest for better service innovation is about better design, engineering, and management of service systems, not science (Bolton et al. 2003; Gluhsko and Tabas 2009; Tidd and Hull 2003; Tien and Berg 2003, 2007; UK Royal Society 2009). However, just as mechanical engineering is informed by the physics of mechanics, service engineering (and the others) can be informed by a science of service. In fact, management science, engineering science, design science, and even engineering economics are all important emerging areas of study, not unrelated to service science. So this view is not really arguing against a science of service, as much as it is arguing for the need for an increase in community activities associated with service management, service engineering, and service design.

The second widely held view, that is not the majority view, is the view that service science is in fact a mosaic of many discipline aligned around the better understanding and innovation of service systems – and so many (all?) sciences contribute to service science (Spohrer and Maglio 2009). Figure 3 below shows the service science transdisciplinary framework, and the thirteen vertical columns represent different types of service systems (all part of holistic service systems in one way or another), and each row corresponds to areas of disciplinary knowledge: marketing (behavioral science), operations (management sciences), governance (political science), strategy (game theory and learning sciences), psychology (cognitive science), industrial engineering (system sciences), computer science (information sciences), knowledge management (organization theory and administrative sciences), economics and law (social sciences), and management of innovation (decision sciences). Again, while there is truth in this view, it does not provide a very satisfying answer to the question of where is the science in service science. If service science has core questions, then the science in service science "must" (in the view of the critics) provide clear mathematical principles and laws that are at the core of the science, as well as methods of observation and experimentation that can grow the body of knowledge and provide deeper answers as well as answers to related questions.

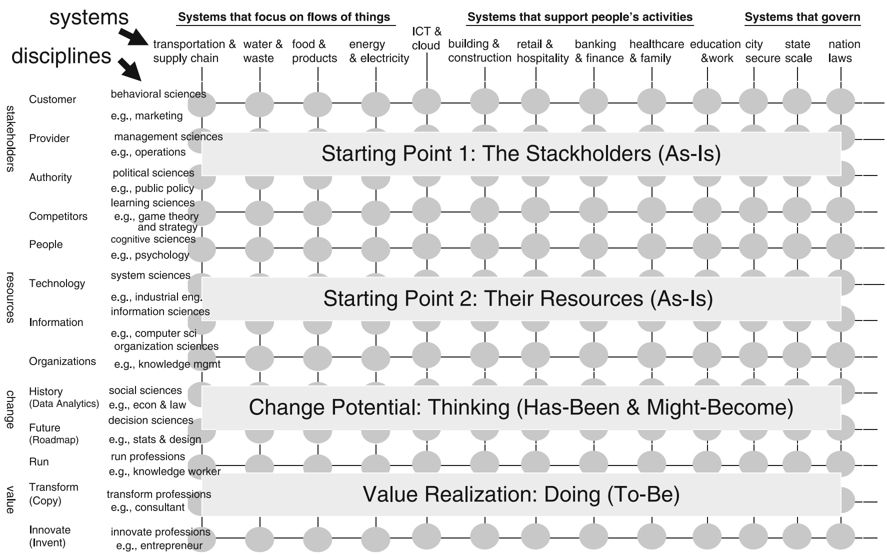


Fig. 3 Service science transdisciplinary framework. (adapted from Spohrer and Maglio 2009)

Despite the prominence of these two alternative views, the majority view in the service science community is based on traditional economics. Just as the majority view of the definition of service is based on the traditional economics view, the majority view on where is the science is based on a traditional economics view. This majority view starts with a question that economists have answered with a mathematically formal model of interaction of entities. When two service systems interact, how likely is it that there exists a value proposition that, if realized, can co-create value for both of them? In economics, Ricardo's Law (1817/2004) says that the law of comparative advantage refers to the ability of an entity (such as an individual, a firm, or a nation) to produce a particular good or service at a lower opportunity cost than another entity. It is the ability to perform work at the highest *relative* efficiency given all possible work allocations that matters most (Normann 2001; Normann and Ramirez 1993). Nations include many businesses that thrive on a variety of types of exchange, and so if in aggregate two nations have complementary competences (i.e., one does one thing better, and the other does another thing better, and both nations need both competences), then clearly a basis for exchange is established, and each nation does a little more of what they do best, and little less of what they do less well. This is the case of complementary competences. However, what Ricardo was able to show was that under a wide range of circumstances, one nation could have superior competencies in all areas, and there still could be an improvement for both entities through interactions that allocate work loads. Furthermore, since experience or learning curves exist in most activities, the longer one engaged in exchange the more benefit both parties could potentially achieve, as increased frequency of work accelerates learning to do the work more efficiently! (Spohrer and Engelbart 2004).

In fact, Ricardo's Law is the starting point to understand "where is the science in service science." Ricardo's Law tells us that distributing work activities or jobs among entities makes quantifiable mathematical sense especially when variations in capabilities exist, even when one entity can do every type of work better than all other entities. In general, value cocreation (or service) opportunities increase rapidly as the number and diversity of entities and types of entities increase. The science of service science asks important questions about the dynamics of value cocreation across space, time, and scale of entities and types of interactions (see question in Sect. 2.7 above).

However, the science of understanding how diverse populations of entities interact with each other and their environment is not the science of economics; it is in fact the science of ecology. Therefore the rising minority view in the service science community is that service science should not be seen as a sub-discipline of economics, and therefore the social science, but instead be seen as a sub-discipline of ecology (writ large) and therefore more of a general systems science. Given the rapid growth of the service economy globally in the last century, one can reasonably ask should service science be thought of as a specialization of economics or ecology? Both of these established sciences, include the term "eco" meaning household, and not surprisingly families are the first types of holistic service systems, and families often become especially stable households when they settle down in a city, a second type of holistic service systems.

But can we say more about where is the science in service science, besides the study of evolution of entities and their interactions within a service (value cocreation) ecology that expands out from families to cities, with their many households and other service systems? And are the service system structure determined only by Ricardo's law and the efficiency of work allocation among entities across space, time, and scale? Holistic service systems like households and cities are important types of entities, but the study of change and limits associated with service (value cocreation) is not complete without including another more recent holistic service system – the university. The increasing knowledge-intensity of the service economy is accelerated by the rise of global universities as holistic service systems. Universities are like mini-cities. Universities are like big-households. The family-household, university, and city are three important types of holistic service systems and the service science community is increasing its study of these types of entities. It should also be noted that hotels are examples of holistic service systems, and the service operations and service marketing communities have made extensive studies of these entities (Fitzsimmons and Fitzsimmons 2007). What principles and laws, beyond Ricardo's Law, can help service scientists understand the dynamics (change, limits) associated with the evolution of value cocreation?

It is beyond the scope of this paper to go deeper into the successes and challenges of this majority view, which suggests that economics is where the science is in service science. Nevertheless, economists have done a remarkable job including households (e.g, family social interactions (Becker 1991)), law (e.g., economics and law (Posner 1973), and resolutions of Pigou's Example (Pigou 1920, 1932) and Braess's Paradox (Braess 1968; Braess et al. 2005; Roughgarden 2001)), and institutional structure (e.g., transaction costs, governance, and new institutional economics (Williamson 1998)), in terms of economic efficiency arguments, which fit within traditional pricing and productivity reasoning of rational agents. However, the predictive powers of which institutional and organizational forms will arise, and even which business models and value propositions will arise, has not been a strong suit of economics (Engelbart 1962, 1980). While economics provides a powerful analytical view of the history of service system evolution, economics has been less successful predicting future forms of service system entities and the value propositions that connect them.

In addition to the Ricardo's Law, "systems-thinking" is another way of reviving the science in service science (Simon 1945/1997, 1996). Systems thinking is the process of understanding how things – systems – influence one another within a whole. Systems thinking is various elements such as air, water, movement, plant and animals work together to survive or perish in ecosystems (Bertalanffy 1976). In organizations, systems consist of people, structures, and processes that work together to provide value. Service, which can be defined as the application of competence and knowledge to create benefit (or value) for another, derives from the interactions of entities known as service systems. Service science (or sciences of the artificial human-made world) has been described as specialization of systems science (Simon 1996).

Systems sciences are scientific disciplines partly based on systems thinking such as Chaos theory, Complex systems, Control theory, Cybernetics, Sociotechnical systems theory, Systems biology, Systems ecology, Systems psychology and the already mentioned Systems dynamics, Systems engineering and Systems theory.

Basically, we can say that the purpose of service science is to study the establishment of an environment for entities to co-create value with benefits to all. Within this context, in the next section, we introduce universal patterns that can possibly occur when abstract entities (service systems) interact and produce outcomes, or Abstract Entity-Interaction-Outcome Universals (AEIOU Theory). AEIOU Theory is part of the emerging minority view, from a systems and ecology "writ large" perspective, of where is the science in service science.

4 AEIOU Theory (Abstract Entity-Interaction-Outcome-Universals)

Where is the science in service science? In the last section, the majority view was introduced with as an economic focus on efficient allocation and distribution of work, guided by the surprising principle of Ricardo's law which factors in the opportunity cost of work, and hence concludes that value propositions can be found between almost all entities, even when one entity does everything better than another. In this section, the emerging minority view is introduced with an ecological focus on sustainability. The emerging principle from this perspective relates to predicting what types of new service system entities are likely to emerge, and suggests a balance exists between productivity and sustainability, between exploitation and exploration (March 1991), and between boredom and challenge (Csíkszentmihályi 1990). Before describing this principle and AEIOU Theory (Abstract-Entity-Interaction-Outcome-Universals), this section first provides an introduction to ecology ("writ large") and suggests that all service scientists should be grounded in this broad view of ecology. The broad view of ecology is not just limited to biology species and environments, but is the science of populations and how they change and limits to growth, and diversity of populations. Ecology ("writ large") is the study of the abundance and distribution of entities in an environment, and how the entities interact with each other and their environment over successive generations of entities (Smith 1986; Begon et al. 2006) (Fig. 4).

Most people think of ecology in terms of living organisms, like plants and animals in a natural environment. However, the concept of ecology is more general and can be applied to entities as diverse as the populations of types of atoms in stars to the types of businesses in a national economy. To relate ecology to service, we must start by thinking broadly about ecologies of entities and their interactions. Eventually, we will get to human-made service system entities and human-made value-cocreation mechanisms... but first, let's really start at the very beginning – the big bang. About 14B years ago (indicated by the top of this purple bar), our universe started with a big bang. And through a process of known as fusion, stars

Fig. 4 Ecology

turned populations of lighter atoms like hydrogen into heavier atoms like helium, and when stars of a certain size have done all the fusion they could, they would start slowing down, and eventually collapse rapidly, go nova, explode and send heavier atoms out into the universe, and eventually new stars form, and the process repeats over and over, creating stars with different populations of types of atoms, including heavier and heavier elements. So where did our sun and the earth come from…. Eventually after about 10B years in the ecology of stars and atoms within stars, a very important star formed our sun (the yellow on the left) – and there were plenty of iron and nickel atoms swirling about as our sun formed, and began to burn 4.5B years ago, and the Earth formed about 4.3B years ago (the blue on the left)… In less than a billion years, the early earth evolved a remarkable ecology of complex molecules, including amino acids, and after less than a billion years, an ecology of bacteria took hold on early earth (the bright green on the left).

The ecology of single cell bacteria flourished and after another billion years of interactions between the bacteria, the first multi cellular organisms formed, and soon the ecology of sponges (the light blue on the left) and other multi-cellular entities began to spread out across the earth. Then after nearly 2B years, a type of division of labor between the cells in multi cellular organism lead to entities with cells acting as neurons in the first clams (the red on the left), and these neurons allowed the clams to open and close at the right time. After only 200 million years, trilobites appeared the first organisms with dense neural structures that could be called brains appeared (the black on the left), and then after about 300 million years, multi-cellular organisms as complex as bees appeared (the olive on the left), and these were social insects, with division of labor among individuals in a population, with queens, drones, worker bees. So 200 million years ago, over 13B years after the big bang, the ecology of living entities is well established on planet earth, including social entities with brains and division of labor between individuals in a population….

Living in colonies that some have compared to human cities – where thousands of individuals live in close proximity and divide up the work that needs to be done to help the colony survive through many, many generations of individuals that come and go. Bees are still here today. And their wingless cousins, called ants, have taken division of labor to incredible levels of complexity in ant cities in nearly every ecological niche on the planet. Now let's look at the human ecology and the formation of service system entities and value-cocreation mechanisms, a small portion of which is represented by the colored bar on the right.

Recall bees appeared about 200 million years ago, a small but still noticeable fraction of the age of the universe as shown on the bar on the left. Now take 1% of this little olive slice, which is 2 million years… that is how long people have been on earth, just one percent of the little olive slice on the left. What did people do in most of that 2 million years? Basically, they spread out to every corner of the planet, and changed their skin color, eye colors, and hair colors, they spread out and became diverse with many different appearances and languages. It took most of that 200 millions just to spread out and cover most of the planet with people. When there was no more room to spread out the density of people in regions went up…

Now take 1% of that 2 million years of human history which basically involved spreading out to every corner of the planet and becoming more diverse, recall ecology is the study of abundance and distribution and types of interactions, and 1% of that 2 million years is just 20,000 years, and now divide that in half and that represents 10,000 years. The bar on the right represents 10,000 years or just 500 generations of people, if a generation is about 20 years. 500 generations ago humans built the first cities, prior to this there were no cities so the roughly 100M people spread out around the world 0% lived in cities, but about 500 generations ago the first cities formed, and division of labor and human-made service interactions based on division of labor took off – this is our human big bang – the explosion of division of labor in cities.

Cities were the big bang for service scientists, because that is when the diversity of specialized roles and division of labor, which is at the heart of a knowledge-based service economy really begins to take off.... So cities are the first really important type of human-made service system entities for service scientists to study, the people living in the city, the urban dwellers or citizens are both customers of and providers of service to each other, and division of labor is the first really important type of human-made value-cocreation mechanism for service scientists to study. (Note families are a very important type of service system entity, arguably more important than cities and certainly much older – however, family structure is more an evolution of primate family structure – and so in a sense is less of a human-made service system entity and more of an inherited service system entity... however, in the early cities often the trades were handed down father to son, and mother to daughter as early service businesses were often family run enterprises in which the children participated – so families specialized and the family names often reflect those specialization – for example, much later in England we get the family names like smith, mason, taylor, cooper, etc.) These family businesses and the specialization of knowledge was like the first B2B outsourcing, but it was F2F (family to family outsourcing). In patriarchal societies, the head man usually was responsible for holding the knowledge and training the apprentices in the next generation.

So to a service scientist, we are very excited about cities as important types of service system entities, and division of labor as an important type of value-cocreation mechanism, and all this really takes off in a big way just 500 generations ago when the world population was just getting to around 100M people spread out all around the world – so 10,000 years about 1% of the worlds population was living in early versions of cities. It wasn't until 1900 that 10% of the world's then nearly 2B people lived in cities, and just this last decade that 50% of the worlds 6B people lived in cities, and by 2050 75% of the worlds projected 10B population will be urban dwellers. If there is a human-made service system that we need to design right, it is cities. It should be noted that the growth of what economist call the service sector, parallels almost exactly the growth of urban population size and increased division-of-labor opportunities that cities enable – so in a very real sense SERVICE GROWTH IS CITY GROWTH OR URBAN POPULATION GROWTH... in the last decade service jobs passed agriculture jobs for the first time, and urban dwellers passed rural dwellers for the first time.

But we are starting to get ahead of ourselves, let's look at how the human-made ecology of service system entities and value-cocreation mechanisms evolved over the last 10,000 years or 500 generations. The population of artifacts with written language on them takes off about 6,000 years ago or about 300 generations ago (the yellow bar on the right). Expertise with symbols helped certain professions form – and the first computers were people writing and processing symbols – scribes were required, another division of labor – so the service of reading and writing, which had a limited market at first began to emerge to help keep better records. Scribes were in many ways the first computers, writing and reading back symbols – and could remember more and more accurately than anyone else.

Written laws (blue on right) that govern human behavior in cities takes off about 5,000 years ago – and this includes laws about property rights, and punishment for crimes. Shortly thereafter, coins become quite common as the first type of standard monetary and weight measurement system (green on right). So legal and economic infrastructure for future service system entities come along about 5,000 years ago, or 250 generations ago, with perhaps 2% of the population living in cities. . . .

(Historical footnote: Paper money doesn't appear much until around about 1,400 years ago – then called bank notes, so use of coins is significantly older than paper money, and paper money really required banks as service system entities before paper money could succeed.).

About 50 generations ago, we get the emergence of another one of the great types of service system entities – namely universities (light blue line) – students are the customers, as well as the employers that need the students. Universities accelerate the division of labor in cities and the supply and demand for specialized skills, including the research discipline skills needed to deepen bodies of knowledge in particular discipline areas. The red line indicates the population of printing presses taking off in the world, and hence the number of books and newspapers. This was only about 500 years or 25 generations ago. Now university faculty and students could more easily get books, and cities began to expand as the world's population grew, and more cities had universities as well. The black line indicates the beginning of the industrial revolution about 200 years ago or 10 generations ago, the steam engine, railroads, telegraph and proliferation of the next great type of service system entity – the manufacturing businesses that benefited from standard parts, technological advances and scale economies, and required professional managers and engineers. About 100 years ago or just 5 generations ago, universities began adding business schools to keep up with the demand for specialized business management skills, and many new engineering disciplines including civil engineering, mechanical engineering, chemical engineering, and electrical engineering, fuel specialization and division of labor (Donofrio et al., 2009). By 1900, just over 100 years ago, or 5 generations ago, 10% of the world's population, or about 200 million people were living in cities and many of those cities had universities or were starting universities. Again fueling specialization, division of labor and the growth of service as a component of the economy are measured by traditional economists.

Finally, just 60 years ago or 3 generations ago, the electronic semiconductor transistor was developed (indicated by the olive colored line on the right), and the information age took off, and many information intensive service activities could now benefit from computers to improve technology (e.g., accounting) and many other areas.

So to recap, cities are one of the oldest and most important type of service system and universities are an important and old type of service system, as well as many types of businesses. Service science is the study of service system entities, their abundance and distribution, and their interactions. Division of labor is one of the most important types of value cocreation mechanisms, and people often need specialized skills to fill roles in service systems. Service science like ecology studies entities and their interactions over successive generations. New types of human-made service system entities and value-cocreation mechanisms continue to form, like Wikipedia and peer production systems. More complex types of holistic service systems, like nations, states, cities/regions, universities, luxury hotels and cruise ships only arise as sustainable entities, if the atomic service system on which they are based has a certainly level of symbolic reasoning capabilities. While "eco" the household, house, or family relationships are the core holistic service system, the atomic service system is the individual person. As we will see in the remainder of this section, *AEIOU Theory provides a way to begin to rank order the capabilities of entities and the types of interactions they can sustain in network structures.*

In Spohrer and Maglio (2009), the authors suggest that the concept of physical symbol system with the capability of reasoning-about-value "symbolically" may provide a fruitful direction of inquiry, when it comes to understanding the range of resource integrators that can design and improve markets. Using the physical symbol system (PSS) criterion, animals and technology (as generic actors and PSS) have a very crude potential to participate in markets as resource integrators, as they have not yet developed adequate symbolic processes-of-valuing capabilities, nor additional capabilities to model other such entities, to realize that potential to design and improve markets (Newell and Simon 1976). So while animals and computers may someday evolve these capabilities, so far markets are a purely human endeavor. The point is simply that the resource integrators must be able to give symbolic names to resources, and reason symbolically about their value to different entities that are also resource integrators. So animals and computers are not generic actors, in the sense that "it is all B2B" implies.

Of course any integrators/actors or resources require interactions. Usually, there are two types of interactions, relational interactions versus transactional interactions. Giddens (1984a, b) provides the philosophical foundations for reasoning about systems in which entities and interactions co-evolve – each shaping the other. Markets emerge when certain types of routine exchange interactions take hold between actors in a population, and those interactions result in sustainable, mutual benefit outcomes. A systems-oriented framework must also examine the types of interactions and outcomes that are possible. The ISPAR (Interact-Service-Propose-Agree-Realize) model is a one of the first steps in this direction (Maglio et al. 2009), but more is needed. ISPAR generalizes the four possible outcomes of a two player game (e.g., win–win, lose–win, win–lose, lose–lose) to include ten possible outcomes of service system entities. Service system entities are the generic actors of service science (Spohrer et al. 2007; Spohrer and Maglio 2009). ISPAR is an example of generalized interactions and outcomes. AEIOU Theory (Abstract Entity-Interaction-Outcome-Universals) is introduced here as an even more abstract systems-oriented framework than ISPAR that may provide a further fruitful path for exploration in looking for universals associated with resource integration and value co-creation phenomena.

Everyday descriptions of entity-interaction-outcome patterns exist for many domains (see Table 1), but, as we will show, AEIOU theory seeks a more formal and universal framework in which to understand entity, interaction, outcome (E-I-O) patterns.

A bit of groundwork connecting service-dominant (S-D) logic and service science is needed, before explaining the details of AEIOU Theory. First, S-D logic is fundamental to the foundations of service science (Maglio and Spohrer 2008). Figure 5 summarizes the ten foundational concepts of service science. Service science is the specialization of systems science that studies value-cocreation interactions between service system entities (Spohrer and Maglio 2009). Elsewhere, these ten concepts of service science have been connected to the ten foundational premises of S-D logic (Service is the fundamental basis of exchange, Indirect exchange masks the fundamental basis of exchange, Goods are distribution mechanisms for service provision, Operant resources are the fundamental source of competitive advantage, All economies are service economies, The customer is always

Table 1 Everyday descriptions of E-I-O patterns for multiple domains

Domain	Entities	Pattern
Physics	Atoms	Fission, fusion, reactions
Physics	celestial bodies	Orbit, collide, sling shot
Chemistry	Molecules	Equilibrium, reactions
Biology	Organisms	Mutualism, consumption
Business	Firms	Exchange, divest, merge
Government	Nations	Trade, dissolution, annex

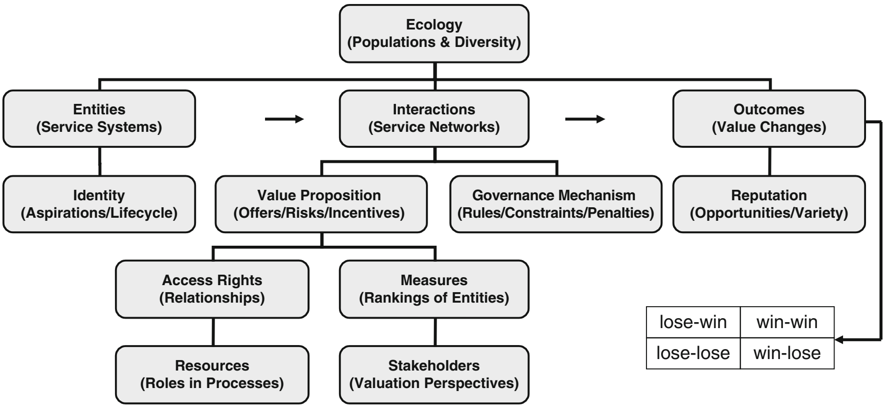


Fig. 5 Ten foundational concepts of service science (Adapted from Spohrer and Maglio 2009)

Table 2 Six questions that AEIOU theory need to answer

Question	Description
1. Does the entity still exist after the interaction?	Some interactions do or do not preserve (conserve) entities.
2. Does the interaction giver rise to new entities?	Some interactions do or do not give rise to new entities.
3. Does the interaction change the state of the entities?	Some interactions do or do not change an entity's state.
4. Does the state change include a record of the interaction?	Some entities can and some cannot record interaction histories.
5. Does the state change include a process-of-valuing the outcome?	Some entities can and some cannot estimate value of outcomes.
6. Does the state change include the result of simulating other entities?	Some entities can and some cannot simulate other entities valuing.

a co-creator of value, The enterprise cannot deliver value, but only offer value propositions, A service-centered view is inherently customer oriented and relational, All economic and social actors are resource integrators, Value is always uniquely and phenomenological determined by the beneficiary) (Lusch and Vargo 2006; Lusch et al. 2008, 2010; Vargo and Lusch 2004a, b). The main concept is that of an *ecology* of entities interacting. The term ecology is preferred over ecosystem to emphasize that population of entities come and go, but the diversity of populations is one measure of the health of the ecology. In fact, we propose that *a service system ecology is a suitable generalization of a market from a systems perspective*.

AEIOU Theory proposes a sequence of binary conditions that can be used to connect generalized systems science to service science and S-D logic. The binary conditions describe the outcomes and capabilities of abstracted entities (Vargo and Lusch's generic actors) when they interact. For example, the first condition is: Does the entity still exist after the interaction? Table 2 summarizes the six conditions that are necessary to achieve entities with value co-creation interaction capabilities that can also design and improve markets.

5 Produce-Distribute-Consume Model

AEIOU Theory could also be called the create-transport-destroy model, or the begin-change-end model, or the input-process-output model. As an example of a more formal framework, Table 3 is one such formalization devised by Betancourt and Gautschi (2001) for the analysis of service institutions based on three primitive economic activities (production-distribution-consumption) that can occur jointly or separately in time and space.

In their conceptual model, Betancourt and Gautschi (2001), they constructed the table based on time and space. On each dimension, they identify five different combinations of these three primitive economic activities (production, distribution,

Table 3 A tableau of primitive economic activities (adapted from Betancourt and Gautschi (2001))

Production, Distribution, Consumption: Jointness { } and Separation ∣		Time				
		{P,D,C}	D∣{P,C}	C∣{P,D}	P∣{C,D}	P∣D∣C
Space	{P,D,C}	1	2	3	4	5
	D∣{P,C}	6	7	8	9	10
	C∣{P,D}	11	12	13	14	15
	P∣{C,D}	16	17	18	19	20
	P∣D∣C	21	22	23	24	25

and consumption), depending on whether they are carried out jointly or separately with one another in each dimension. The table includes two cases: joint-ness in time and space of production, distribution, and consumption, and separation in time and space of production, distribution, and consumption. They identify twenty five configurations of the primitive economic activities. They define that all economic agents (producers, distributors and consumers) have production functions. The boundary between production and distribution is determined in any context by the consumption. The output of a production is intended to fulfill a consumption of customer; the output of a distribution activity is intended to permit such fulfillment. The conceptual distinction of the primitives and the ordered connections between them implies the imposition of certain relational constraints. These relational constraints, for example, restrict how a commodity can be consumed and, consequently, have the welfare enhancing effect of reducing uncertainty with respect to the feasibility of alternative consumption procedures.

Interactions between these economic agents can be spread out across scale as well as space and time – sort of up and down hierarchically more complex systems – like people inside departments inside businesses inside nations, etc. – all different scale entities. We propose the Abstract Entity-Interaction-Outcomes (AEIOU) theory to discuss the science of service systems.

Recent research suggests that inseparability is not a universal distinguishing characteristic of services and that the consumption of many services is or can be separated from their production. The AEIOU theory defines service separation as customers' absence from service production, which denotes the spatial separation between service production and consumption. We assume that service separation increases customers' perceptions of not only access convenience and benefit convenience but also performance risk and psychological risk. Furthermore, these effects differ across services. Specifically, relative to experience services, for credence services, the effects of separation on service convenience are mitigated, and the effects on perceived risk are magnified. Subsequently, the convenience and risk perceptions induced by service separation can influence customers' purchase decisions and post-experience evaluations. Customers prefer separation for experience services and when they have an established relationship with the service provider.

In "Sciences of the Artificial," Simon (1996) embarked on an inquiry not unlike service science. As natural sciences explain the origin and evolution of natural things, so sciences of the artificial explain the origin and evolution of artificial things. Artificial things are designed by humans to serve a human purpose. Value cocreation is an example of a general human purpose. If interactions are costly but necessary, and they are, then value cocreation is a logical purpose, which when achieved can grow and sustain interactions. In this sense, value cocreation is autocatalytic and self reinforcing (Bardhan et al. 2010). More simply, value cocreation is the type of human purpose that can amplify itself. Service science is value cocreation science, and studies service system entities and their interaction mechanisms, both value-proposition-based and governance-mechanism-based according to the AEIOU theory.

We claim the human purpose of science is to understand ultimately how things change, and thereby better understand where we came from (satisfy curiosity) and where we can go (create opportunity). Because we are aware of the world and our lack of knowledge limits our ability to shape both own individual destiny as well as the destiny of others, we humans have developed science as a tool with a purpose. Therefore, we might propose that the purpose of science is for the human population to gain and apply knowledge to benefit ourselves and others. Given this proposed purpose of science, how can we better understand the type of science that service science is seeking to become? For example, how are we to understand abstract entities (service systems), interactions (value cocreation mechanisms) and outcomes in the service ecology?

6 Concluding Remarks

Change happens for a reason. Mechanisms underlie all events, and all change. Scientists work to identify and validate symbolic representations of mechanisms. For example, "F=MA" and "E=MC2" are two well-known, beautifully concise, symbolic representations that reflect underlying mechanisms of change in the world. If change is predictable (by humans), it is because the mechanisms are stable. From a service science perspective, the human-made world arose from the physical-chemical-biological-social world when people began to trust and depend on service (value cocreation) mechanisms (e.g., division of labor) the way they trust and depend on natural mechanisms (e.g., this tree will bear fruit next season). Of course, a tree bearing fruit does not require trust to operate, but division of labor does. Nevertheless, our point is a simple one: *service science seeks to be a science based on reliable mechanisms*, just as natural science is based on reliable mechanisms. From a human perspective, sometimes natural mechanisms (seemingly) fail to act reliably. This may be because assumptions are invalid, or other mechanisms are at work (e.g., a plane would fall from the sky, if not for Bernoulli's principle). The same is true of service (value cocreation) mechanisms. If assumptions are invalid or other mechanisms are at work, then predictions may not be reliable. For example, when a computer program does not operate as predicted, we know it is because of invalid assumptions or other mechanisms at work. Science works to discover mechanisms, and to expose invalid assumptions and other mechanisms at work.

In the human-made world of service system entities interacting, trust is an important input to ensure mechanisms (value propositions) work as agreed. When value propositions fail, trust begins to diminish. Restoring trust between entities can be difficult. As outlined in AEIOU Theory, entities must have internal mechanisms that allow them to model other entities and evaluate value propositions proposed by those other entities. Service system entities are a type of physical symbol system, and that level of entity is required to model other entities, evaluate value propositions, and factor in levels of trust (Spohrer and Maglio 2009).

For service science to graduate to the level of the natural sciences, new representation languages are needed to express valid symbolic representations of mechanisms. In general, the systems sciences that study complex systems and networks struggle with this challenge. Much of economics and ecology still depend on differential equations to model the quantitative interactions. The system sciences, economics, ecology, and now service science must work to identify and validate symbolic representations of mechanisms far more complex that can be adequately captured even with a system of differential equations. Much fundamental work in mathematical representations of systems and networks remains to be done to enable the service science community to identify and validate symbolic representations of mechanisms.

However, before those valid symbolic representations of mechanisms can be identified, service science needs to establish a community of researchers who agree on a common set of concept and a world view that allows them to ensure they are talking about the same set of entities, interactions, and outcomes. This has been one of the main contributions of the service science community to date. Vargo and Lusch have provided a framework that allows all interactions to be seen as service for service exchange (2007, 2008, 2008a, b, 2009). Gummesson has provided a framework that allows very practical everyday experiences to be seen as networks of interacting service system entities (Gummesson 2007). Bitner and colleagues have developed Service Blueprinting as a framework for modeling many of the service interactions people engage in everyday (Bitner 1995; Bitner and Brown 2006). Maglio et al. (2009) have provided a framework for understanding the possible outcomes when service system entities interact, both service and non-service interactions. Rust and colleagues have provided frameworks for understanding the life-time value of customers, as well as interactions of investments in productivity and quality over the life-time of provider entities in competitive environments (Rust 2004; Rust et al. 2000). Ng and colleagues have provided a framework for understanding and managing for outcomes. Spohrer and Maglio (2008, 2009) have summarized the foundational concepts, as well as the four fundamental types of resources, access rights, stakeholders, and measures associated with service system entities interacting via value propositions and governance mechanisms. March (1991), Csíkszentmihályi (1990), as well as Spohrer and Maglio (2008, 2009) have provided frameworks for how organizations

(Exploitation and Exploration), individuals (Flow, balancing Boredom and Challenge), and service system entities (Run-Transform-Innovate Investments) change over time. All of these and many more of the contributions of the service science community to date are summarized in the Handbook of Service Science (Maglio et al. 2010). In addition, Demirkan and his colleagues provided frameworks to evaluate the impact of service orientation, as well as coordination mechanisms for service oriented supply chain mechanisms, and defined research priorities for the Science of Service (Demirkan and Goul 2008; Demirkan and Spohrer 2010; Demirkan et al. 2010; Harmon and Demirkan 2011; Ostrom et al. 2010).

While the work in mathematics is probably the most fundamental work that needs progress in order to accelerate advancements in service science, the ability to model hierarchical networks of some ten billion service system entities with computational tools (e.g., Computer-Aided Design or CAD tools) is also currently lacking. Real progress in answering the second question "Where is the science in service science?" will depend on progress in these two areas, mathematics and computer modeling. However, we should not under value the decades of empirical studies of the service research community, nor the pioneering works in these two volumes by the growing service science community, gradually aligning around common language and definition of terms. The foundations being put in place today by the service science community are fundamental in nature. Though much work remains ahead, and nothing is settled.

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